Improvement of drill system for the third deep ice coring project around Dome Fuji, Antarctica - Focusing on selection of drilling fluids -

Atsushi FURUSAKI[1], Hideaki MOTOYAMA[2,3], Morimasa TAKATA[4], Fumio NAKAZAWA[2,3], Kenji KAWAMURA[2,3], Sumito MATOBA[5], Shoichi MORI[5], Yosuke SATO[5], Kunio SHINBORI[5], Morihiro MIYAHARA[6], Akio KOBAYASHI[7],Yasushi YOSHISE[7], Masateru OTANI[7], Akiyoshi TAKAHASHI[8] and Yoichi TANAKA[9]

[1]National Institute of Technology, Asahikawa College, [2]National Institute of Polar Research, [3]The Graduate University for Advanced Studies, SOKENDAI, [4]Nagaoka University of Technology, [5]Institute of Low Temperature Science, Hokkaido University, [6]ANORI Inc., [7]OLYMPIA KOGYO Co Ltd., [8]Geo Tecs Co. Ltd, [9]Geosystems Inc.

Past and scheduled deep ice coring project at Dome Fuji

- The first deep ice coring project at Dome Fuji, Antarctica (DF1) reached a depth of 2503m in December1996. The age of the deepest ice core obtained was 340,000 years.
- The second deep ice coring project at Dome Fuji, Antarctica (DF2) reached a depth of 3035.22 m in January 2007. The age of the deepest ice core was 720,000 years.
- In response to IPICS 'OLDEST ICE', the third deep ice coring project (DF3) is underway to obtain ice cores older than 800,000 years. In our proposed site estimation, maximum ice sheet depth will be 2,500m around Dome Fuji area.

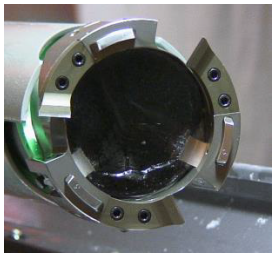
Improvement of drill system for DF3

(1) New **communication and control systems** between the surface and the drill are currently under development.

(2) Design and dry/wet ice drilling experiments for **step cutters** are being conducted to make even better things..

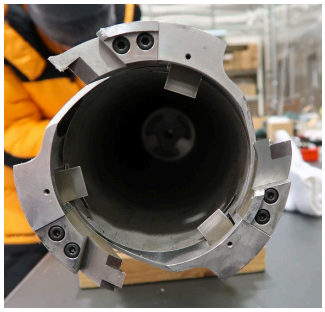
➡ We are currently developing and producing a new deep drill system, especially cutter equipment. But there were no major design changes in the machine itself.

Normal cutter for DF2



Dolphin cutter for deep warm ice for DF2

A step cutter often shaves the ice with low power consumption and low torque, so it has been used in shallow drilling of mountain glacier and deep drilling in Greenland.



Prototype I step cutter

↓

Dry drilling experiment was conducted in December 2018 at NIPR.

Prototype II step cutter

↓

Scheduled to conduct dry and wet drilling experiments at the end of October 2019.

Fig.1 Drill cutters of normal and dolphin-type for DF2, and new prototypes for DF3.

(3) Experiments with drilling fluids selection were performed with silicone oil (Shin-Etsu Chemical Co. Ltd. ; KF96L-1.5cSt) and n-butyl acetate (Wako Pure Chemical Industries, Ltd. ; 1st Grade).

➡ Kinetic viscosity, viscosity and descending speed in liquid were measured for the both liquids, and chemical corrosion test with n-butyl acetate was performed.

【Experiment 1 ; Kinematic viscosity under several temperatures】

- The kinematic viscosities under several temperatures were measured with Ubbelohde viscometers. ➡ Fig.2

❖ **The kinetic viscosity of silicone oil at -10 °C is about 3.1 times higher than that of butyl acetate.**

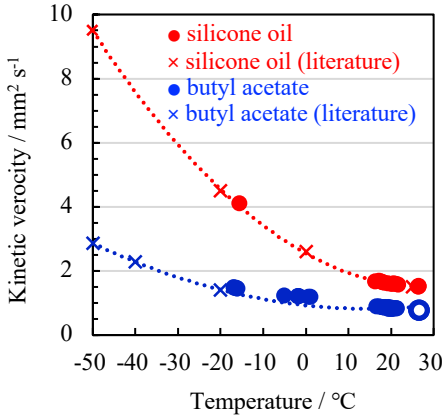


Fig.2 Kinetic viscosity of silicone oil and n-butyl acetate

【Experiment 2 ; Viscosity under normal / high pressure】

・The viscosity under 8 MPa was measured with a high-pressure cell manufactured by Anton Paar Japan. ➡ Table.1

❖ **The viscosity of silicone oil at -10 ℃ is about 2.5 times higher than that of butyl acetate whether under normal pressure or under 8MPa.**

Table.1 Viscosity of silicone oil and n-butyl acetate

Test liquid	Pressure / MPa	Viscosity / mPa･s	
		-10℃	20℃
N-butyl acetate (A)	0.10	1.14	0.67
	8.0	1.20	–
Silicone oil (B) KF96L-1.5cSt	0.10	2.8	1.6
	8.0	2.9	–
Ratio （B/A）	0.10	**2.5**	2.2
	8.0	**2.4**	–

【Experiment 3 ; Descending speed in liquid】

・Fill each glass / acrylic tube with an inner diameter of 18.0 mmφ and a length 1.0-1.5m.
・A glass test tube with an outer diameter of 16.5mmφ, a length of 75mm (mass set to 23.1g / 30.0g) was dropped freely.
・Measures the time required to move between two points (80.0cm). ➡ Fig.3

❖ **The descent speed in silicone oil at -18℃ is 0.38 to 0.45 times lower than that in n-butyl acetate. So the actual drilling time is more than doubled.**

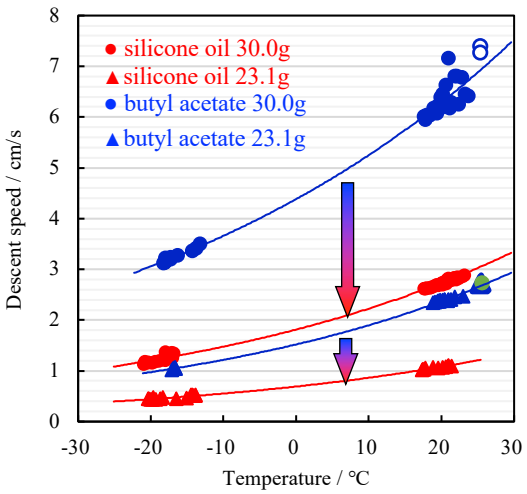


Fig.3 Descent speed in silicone oil and n-butyl acetate

【Experiment 4 ; Chemical corrosion test】

・Some pieces of casing pipe (about 87mm-L x 13mm-W) were immersing in n-butyl acetate under room temperature and -50℃.
・After immersing for one month, we performed a tensile test on the specimens. ➡ Fig.4,5

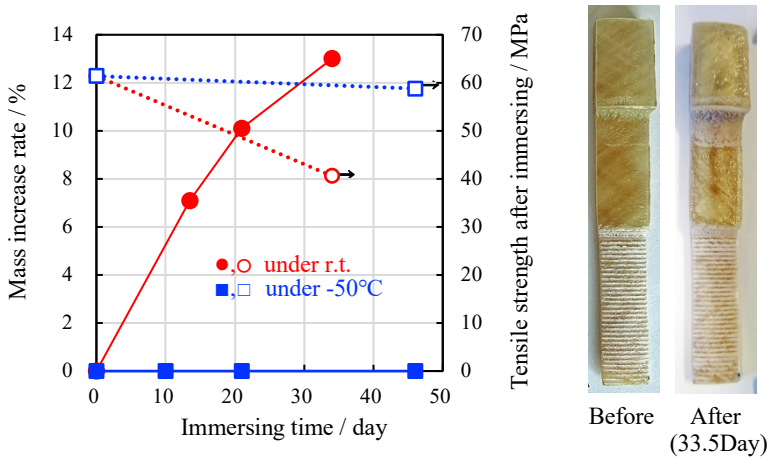


Fig.4 Changes in mass, tensile strength and appearance due to immersion

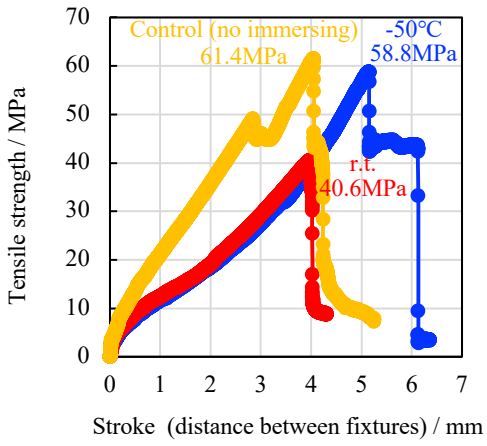


Fig.5 Tensile test

❖ **(1) When immersed under r.t. for 34 days, the mass of sample pieces increased by about 13% and the tensile strength decreased by about 34%.**
(2) But under -50℃, it showed no mass change and the tensile strength hardly changed.

Conclusion on selection of drilling fluid

・At Dome Fuji, the borehole temperature is still–20℃ even at 2,250 m depth. Since silicone oil is highly viscous at such low temperature, it causes a significant reduction in drilling efficiency.
・N-butyl acetate will attack the resin of casing pipe under room temperature, but has no effect under -50℃.

Because of the above properties and the cost (n-butyl acetate ; ¥250/kg, silicone oil ; ¥2,200/kg), **n-butyl acetate is preferred**.